PATENT SPECIFICATION

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(54) DIAPHRAGM PUMP, PARTICULARLY FOR THE GENERATION OF VACUUM

(71) I, ERICH BECKER, of German Nationality, of No. 80, Lichtenbergstrasse, Freiburg, Federal Republic of Germany, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a diaphragm pump, particularly for the generation of vacuum, in which the central portion of the diaphragm is attached to a connecting rod, whereas its periphery is fixed in the pump chamber or some other part of the crankcase or housing of the pump.

Diaphragm pumps of this kind are known in art. A difficulty which arises in such diaphragm pumps is that of reducing or eliminating the deadspace of the pump which is due to the clearance that remains above the diaphragm at top dead centre. This deadspace prevents the generation of a high vacuum and thereby reduces the performance of such a diaphragm pump.

Also known in the art are diaphragm pumps comprising a plurality of pumping elements working in series and disposed about a common drive shaft. However, the attainable vacuum cannot thus be substantially improved despite a considerable increase in cost.

According to the invention there is provided a diaphragm pump comprising a housing, a diaphragm having its periphery secured to the housing, said diaphragm having a thickened relatively inflexible central portion and an annular flexible outer portion, said central portion being secured to a connecting rod pivotally mounted on a crank, a pump chamber being defined between said diaphragm and a wall of said housing, said central portion of said diaphragm being substantially spherically convex having a centre of curvature lying substantially on the pivot axis of said connecting rod, and said housing wall having a central portion which is substantially spherically concave to match the convex portion of said diaphragm and has a radius of curvature the same as or slightly exceeding that of said convex portion, the arrangement being such that when said diaphragm has completed the displacement of fluid from said pump chamber, said diaphragm is in substantially overall surface contact with said housing wall.

A useful preferred feature is for the diaphragm to have zones of material of differing flexibility and hardness because particularly in the peripheral region this facilitates surface contact being made with the facing inner surface of the housing wall. It may be desirable at least in one portion of the diaphragm to provide a stiffening insertion which modifies its natural flexibility. Preferably this will be the central portion which adjoins a downwardly extending hub-shaped projection on the diaphragm which is preferably provided in order to mount the diaphragm on the one end of the connecting rod. The suitably shaped stiffening insertion matches the configuration of the facing central portion of the inner surface of the housing wall. These zones of different flexibility and the reinforcing insertion enable the diaphragm flexibly to move into surface contact with the inner surface of the housing wall in synchronism with the cyclic motions of the connecting rod.

Moreover it has been found that it is an advantage if the crankcase or any other chamber adjoining the back of the diaphragm contains a gauge pressure which acts on the back of the diaphragm. This can be arranged by providing the crankcase with a suction valve and with a constant pressure valve for maintaining a given slight gauge pressure which will urge the flexible portions of the diaphragm at top dead centre into surface contact with the inner surface of the housing wall and which will thereby

1. Hier handelt es sich um die Schaffung eines Überdruckes im Pumpengehäuse damit die Arbeitsmembran sich nach oben beult und somit den Totraum minimi
2. Es ist keine zweite Membrane vorhanden.
3. Bei PC 00 396 B handelt es sich um Unterdruck, der die

assist in the generation of vacuum. Alternatively a supply of compressed air from an extraneous source could be provided.

A metal member may be attached, preferably vulcanised, to the hub-shaped projection of the diaphragm for securing the diaphragm to the one end of the connecting rod in such a way that according to the configuration and elasticity of the hub-shaped projection the diaphragm will participate in the swinging lateral motions of the connecting rod or absorb them.

The proposed diaphragm pump may also be constructed as a two stage pump and correspondingly provided with two diaphragms symmetrically disposed about a plane intersecting the axis of rotation of the crank drive. If the two pump chambers are connected to work in series a substantially better vacuum can be attained.

Some embodiments of the invention will now be described by way of example and with reference to the accompanying schematic drawings, in which:—

Fig. 1 is a longitudinal section of a diaphragm pump according to the invention showing the connecting rod at top dead centre;

Fig. 2 is a longitudinal section of the same diaphragm pump as in Fig. 1, showing the connecting rod at bottom dead centre;

Fig. 3 is a like longitudinal section of a slightly modified diaphragm pump, showing the connecting rod in mid-stroke position;

Fig. 4 is a longitudinal section of the diaphragm pump according to Fig. 3 but differing therefrom in that the wall facing the top of the diaphragm is slightly convexly raised into closer proximity with the diaphragm;

Fig. 5 is a longitudinal section of a diaphragm pump having a crankcase fitted with a suction valve and a constant pressure valve, and

Fig. 6 is a longitudinal section of a two-stage diaphragm pump according to the invention.

Referring first to Fig. 1 it will be seen that at top dead centre of a connecting rod 3 the diaphragm 2 of a diaphragm pump 1 makes full surface contact with the inner surface 4 of the upper wall of a crankcase or housing K. The spherical configuration of the facing zones of the diaphragm 2 and the inner surface 4 of the upper wall of the crankcase is also clearly apparent. The diaphragm 2 has a downwardly extending hub-shaped projection 9 which is secured to the upper end of the connecting rod 3 by means of a metal member 26 which is preferably vulcanised to said hub-shaped projection.

Fig. 2 shows the same diaphragm pump at bottom dead centre of the connecting rod 3 and illustrates how in this position the inner surface 4 of the crankcase wall and the diaphragm 2 form a pump chamber 5 between them. Also the changed shape of the diaphragm 2 reveals the presence of flexible zones 21 in the regions 6, 7 and 6', 7' and of a relatively inflexible zone 8 in the middle of the diaphragm 2, said relatively inflexible zone 8 being due to a stiffening insertion 23 in the diaphragm 2. The configuration of that portion of the inner surface 4 of the upper wall of the crankcase which faces the flexible zones 21 of the diaphragm is that of a truncated cone 30.

As will be readily understood from Fig. 3 and 4, the pump is provided with an exhaust port 11 so disposed that it is the last to be covered by the diaphragm 2 at the end of the corresponding stroke of the connecting rod 3. Consequently, and also because the diaphragm 2 makes substantially complete surface contact with the inner surface 4 of the upper wall of the crankcase, residual clearance in the pump chamber 5 is completely eliminated. The dead space of the pump is therefore extremely small, comprising the very minor capacity of the exhaust port 11. During the descent of the connecting rod 3 the diaphragm 2 first loses contact with the inner surface 4 in the regions 7' and 6' by reason of the obliquity of the connecting rod 3 in this phase. Hence an inlet port 10 provided in the upper wall of the crankcase and associated with an inlet valve 50 is uncovered first, permitting aspiration to begin which continues to bottom dead centre of the connecting rod 3. It is also indicated in Fig. 4 that the inner surface 4 of the upper wall of the crankcase has a slight convex camber at 4' facing the diaphragm zones 6 and 7 in order to establish particularly tight contact in these zones on the far side of the exhaust port 11 even when the exhausting pressure in these zones is fairly high.

Fig. 5 shows a suction valve 12 fitted in the side wall of the crankcase K to provide a slight gauge pressure loading the back, i.e. the inner surface 24 of the diaphragm 2, said slight gauge pressure being then kept constant by a constant pressure valve 13 which is likewise fitted in the side wall of the crankcase. The presence of this slight gauge pressure in the crankcase K prevents the diaphragm 2 from undesirably bulging downwards and thus also contributes towards ensuring that the diaphragm 2 will make full surface contact with the inner surface 4 of the upper wall of the crankcase at top dead centre of the connecting rod 3. This slight gauge pressure arises because air is drawn into the crankcase K through the suction valve 12 when the diaphragm 2 is pushed upwards. During the downstroke of the connecting rod 3 the diaphragm 2 compresses this air in the crankcase K. When the desired pressure is exceeded air is

exhausted through the suitably biased constant pressure valve 13.

Alternatively compressed air from an extraneous source may be used to generate a slight gauge pressure inside the crankcase K with a view to assisting the diaphragm 2 in making the desired surface contact with the inner surface 4 of the upper wall of the crankcase at top dead centre of the connecting rod 3.

The proposed diaphragm pump may also be designed to function as a multi-stage diaphragm pump, for instance as a two-stage diaphragm pump illustrated in Fig. 6. In this embodiment the suction valve 12 and the constant pressure valve 13 shown in Fig. 5 may be dispensed with. The first stage comprising the diaphragm 2 displaces a larger volume inside the crankcase K than the second stage diaphragm 14, which is connected to the lower end of a connecting rod 3' and cooperates with the inner surface 15 of the bottom wall of the crankcase. However, if desired, the suction valve 12 and the constant pressure valve 13 in Fig. 5 may nevertheless be fitted in the embodiment of the two-stage diaphragm pump illustrated in Fig. 6. In the embodiment according to Fig. 6 it is also important that no clearance space remains in the second stage. This diaphragm 14 must therefore likewise make complete surface contact with the inner surface 15 of the bottom wall of the crankcase. During the withdrawal of the diaphragm 2 of the first stage and the simultaneous advance of the diaphragm 14 of the second stage, the first stage diaphragm 2 displaces more air than can be accommodated at constant pressure in the volume made available by the second stage diaphragm 14, so that the consequent rise in pressure inside the crankcase K will ensure that the second stage diaphragm 14 makes full surface contact with the inner surface 15 of the bottom wall of the crankcase.

Whereas diaphragm pumps hitherto known in the art permit vacuum pressures up to 76 torrs to be achieved, a single stage vacuum pump using a surface-contact diaphragm as proposed by the invention can achieve a vacuum pressure of approximately only 1.5 torrs, whereas the two-stage diaphragm pump using surface-contact diaphragms can achieve a vacuum of approximately only 1 torr. These data illustrate the improvement in performance that is attained by a surface-contact diaphragm pump proposed by the invention by comparison with diaphragm pumps of conventional kind.

The two-stage diaphragm pump shown in Fig. 6 comprises two shaped surface-contact diaphragms 2 and 14 constructed in accordance with the invention. Naturally the proposed diaphragm pump can also be designed as a multi-stage diaphragm pump in a conventional manner, comprising three, four or more stages. The fluid aspirated into the first pump chamber 5, as shown in Fig. 6, is transferred into the next following pump chamber for the purpose of achieving a higher vacuum. The same would also apply to a diaphragm pump used for the generation of pressure.

If the diaphragm pump is operated as a vacuum pump, it works as follows:—

Let it be assumed that initially the diaphragm 2 is in the position shown in Fig. 1. The pressure existing in the pump chamber 5 is at first that of a vacuum (the effect of the volume of fluid which has remained in the inlet port 10 and in the exhaust port 11 may be neglected for the purposes of this explanation). For aspiration the connecting rod 3 and the diaphragm 2 both move into the positions shown in Fig. 2. Fluid will now have entered the pump chamber 5. During the ensuing exhaust stroke (cf. Fig. 3 or Fig. 4) the pressure in the pump chamber 5 rises. For example, during the exhaust stroke the pressure in the pump chamber may rise to something above 1 atm. because the fluid must be exhausted against atmospheric pressure besides having to overcome for instance the resistance of a valve associated with the exhaust port 11 and generally a slight resistance to flow. Consequently, during exhaustion a slightly higher pressure will act on the diaphragm 2 from inside the pump chamber 5 than from inside the crankcase K. The diaphragm 2 may therefore assume a shape, particularly in the regions 6 and 7, which is as illustrated in Fig. 4. In these regions the diaphragm 2 tends to bulge slightly into the crankcase K. This would impede the contemplated effect of substantially eliminating residual clearances in the pump chamber 5. As proposed by the invention this unwanted result can be completely or at least substantially avoided by taking appropriate measures. One of these measures is clearly illustrated in Fig. 4 and consists in providing the upper wall of the pump chamber 5, i.e. the inner surface 4 of the upper wall of the crankcase, in that region which faces the portion of the diaphragm 2 that bulges into the crankcase K with the corresponding convex camber 4'. Despite unfavourable pressure conditions acting on the diaphragm 2 from above and/or from below in the region of the camber 4' of the upper wall, the diaphragm 2 will now be able to make the desired full contact with the upper wall of the pump chamber 5.

An alternative step that can be taken consists in raising the pressure in the crankcase K beyond that existing in the chamber from which the pumped fluid is exhausted. The pressure inside the crankcase will

normally be slightly above atmospheric when the pump is being used as a vacuum pump. For instance in the crankcase K the pressure may be between 1.1 and 1.2 atmospheres in which case this pressure will operate in the critical region to urge the diaphragm 2 in the direction of the arrows PF 10 in Fig. 5 into contact with the inner surface 4 of the upper wall of the crankcase. Naturally this pressure differential will also assist in making every portion of the diaphragm 2 move into tight contact with the said surface 4. Naturally the two above-described steps illustrated in Figs. 4 and 5 may be simultaneously taken and the same applies to one-stage and multi-stage diaphragm pumps proposed by the invention.

The spherical surface configuration of the central portion of the inner surface of the upper wall of the crankcase and the conforming contour of the diaphragm 2 have substantial advantages over conventional mushroom-shaped cross sections at the end of the connecting rod; In the prior art mushroom-shaped contour in the region where the connecting rod and the diaphragm join the edge of the mushroom cannot as closely approach the inner surface 4 of the upper wall of the crankcase as would be desirable for achieving complete surface contact of the diaphragm with the said surface. In the conventional configuration of the connecting rod the junction between the connecting rod and the diaphragm and of the associated conventional contour lines of the inner surface 4 of the upper wall of the crankcase there is always a likelihood of the edges of the "connecting rod mushroom" approaching the inner surface 4 too closely and thus generating a considerable amount of noise and/or subjecting the diaphragm 2 to an overload. Alternatively the adverse effect of some clearance space must be accepted. The spherical shape of the inner surface 4 in the central upper portion and the corresponding configuration of the diaphragm 2 in this portion, particularly when the specified relationship between the radii R 1 and R 2 is observed, enable the diaphragm 2 during the compression or exhaust stroke to roll on the inner surface 4 in accordance with the movement of the connecting rod. This rolling motion not only favours the creation of surface contact between the diaphragm 2 and the inner surface 4, but also avoids the generation of noise and of unnecessary relative motion between the diaphragm 2 and the inner surface 4 which might be responsible for the appearance of wear.

Finally it should be mentioned that at the transition at 22 on the diaphragm 2 there is an increase in section, as will be readily seen when referring to the cross section in these portions of the diaphragm 2 ~~as~~ illustrated in Fig. 1 and Fig. 2. The more pronounced increase in section at the transition 22 ensures that the movements of the connecting rod 3 will not merely be shared by the material directly above the upper end of the connecting rod 3 but also by that on the sides towards the fixed edges of the diaphragm 2. This is favoured by the substantially mushroom-like contour and the thickening of the section of the diaphragm in the region defined by references 7, 8 and 7'.

It should further be noted that the less flexible zone of the diaphragm 2, i.e. the region defined by references 7, 8 and 7' above the upper end of the connecting rod 3, may have a shore hardness exceeding 80, whereas the more flexible zone towards the periphery, as defined by the reference numbers 6, 7 and 6', 7' should have a shore hardness of about 40 to 80. These different hardnesses are also a measure of the flexibilities.

However, an analogous distribution of flexibilities can already be achieved exclusively by the configuration and thickness of the diaphragm portions, as is well illustrated in Fig. 1. If the entire diaphragm 2 is made of one and the same material, for example of rubber having a shore hardness of about 60, then differences in flexibility will be achieved merely by the fact that the diaphragm regions defined between references 6 and 7, and 6' and 7', are thin and therefore more easy to bend than the region in the centre defined by reference numbers 7, 8, 7' where the configuration provides a greater accumulation of material directly above the upper end of the connecting rod 3 and thus imparts a stiffer and less flexible character to this region.

All the above features may be of importance to the invention either severally or in any combination.

Finally, it is self-evident that instead of the upper and/or bottom wall of the crankcase as hereinbefore described any other partition wall fixed in the crankcase or housing of the pump can be used for providing the inner surface or surfaces with which the diaphragm or diaphragms cooperate.

WHAT I CLAIM IS:—

1. A diaphragm pump comprising a housing, a diaphragm having its periphery secured to the housing, said diaphragm having a thickened relatively inflexible central portion and an annular flexible outer portion, said central portion being secured to a connecting rod pivotally mounted on a crank, a pump chamber being defined between said diaphragm and a wall of said

housing, said central portion of said diaphragm being substantially spherically c nvex having a centre of curvature lying substantially on the pivot axis of said connecting rod, and said housing wall having a central portion which is substantially spherically concave to match the convex portion of said diaphragm and has a radius of curvature the same as or slightly exceeding that of said convex portion, the arrangement being such that when said diaphragm has completed the displacement of fluid from said pump chamber, said diaphragm is in substantially overall surface contact with said housing wall.

2. A diaphragm pump as claimed in claim 1, wherein that part of the housing wall which faces the last portion of the diaphragm to make contact with the housing wall as the connecting rod approaches the top dead centre position, is formed with a convex projection to improve the surface contact of said diaphragm with said housing wall.

3. A diaphragm pump as claimed in claim 2, wherein the portion of the housing wall which is to contact the flexible outer portion of the diaphragm has the shape of a truncated cone, on which said convex projection is formed.

4. A diaphragm pump as claimed in claims 1, 2 or 3 wherein the diaphragm has regions of material with differing flexibilities.

5. A diaphragm pump as claimed in claim 4, wherein the shore hardness of the annular flexible outer portion of the diaphragm is between 40 and 80, and the shore hardness of the central portion is greater than 80.

6. A diaphragm pump as claimed in any preceding claim, wherein a stiffening insertion is provided in the central portion of the diaphragm.

7. [redacted] claimed in any preceding claim, wherein the interior of the housing is provided with a gauge pressure loading the side of the diaphragm remote from the pump chamber.

8. A diaphragm pump as claimed in claim 7, wherein the interior of the housing on the side of the diaphragm remote from the pump chamber is fitted with a suction valve and preferably with a constant pressure valve.

9. A diaphragm pump as claimed in any preceding claim, wherein the diaphragm is formed with a hub-shaped projection secured to the connecting rod.

10. A diaphragm pump as claimed in claim 9, wherein a metal member is attached, preferably vulcanised, to the diaphragm for securing the hub-shaped projection of the diaphragm to the connecting rod.

11. A diaphragm pump substantially as hereinbefore described with reference to Figs. 1 to 5 of the accompanying drawings.

12. A diaphragm pump assembly comprising two diaphragm pumps as claimed in any of claims 1 to 10, disposed in opposition to one another with a common crank drive, the inlet of one pump chamber being connected to the outlet of the other pump chamber whereby to form a two-stage pump.

13. A diaphragm pump assembly substantially as hereinbefore described with reference to Fig. 6 of the accompanying drawings.

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6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1

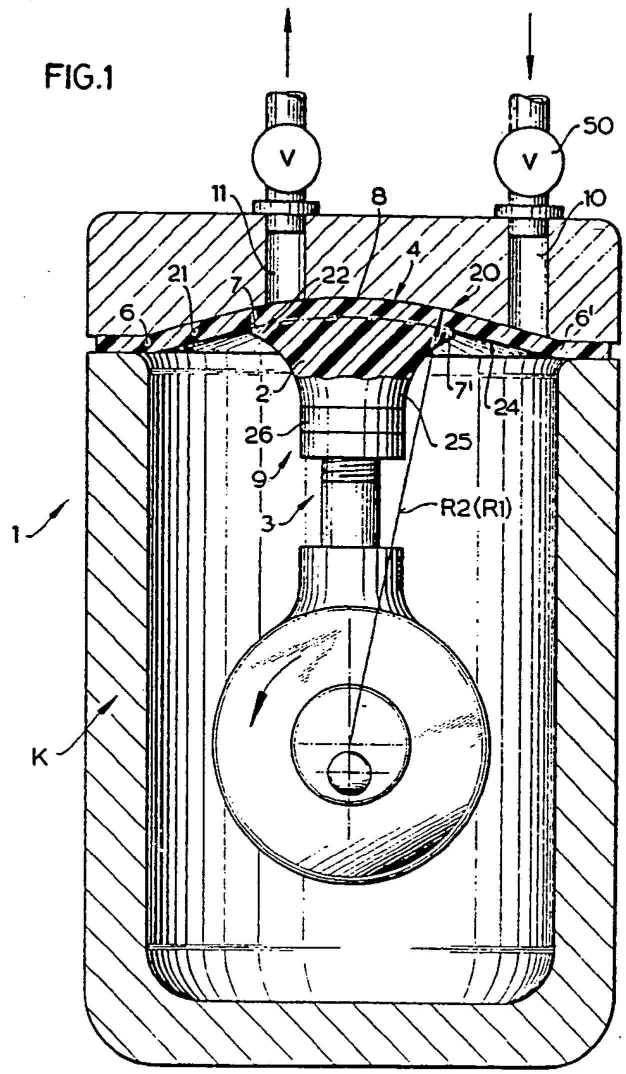
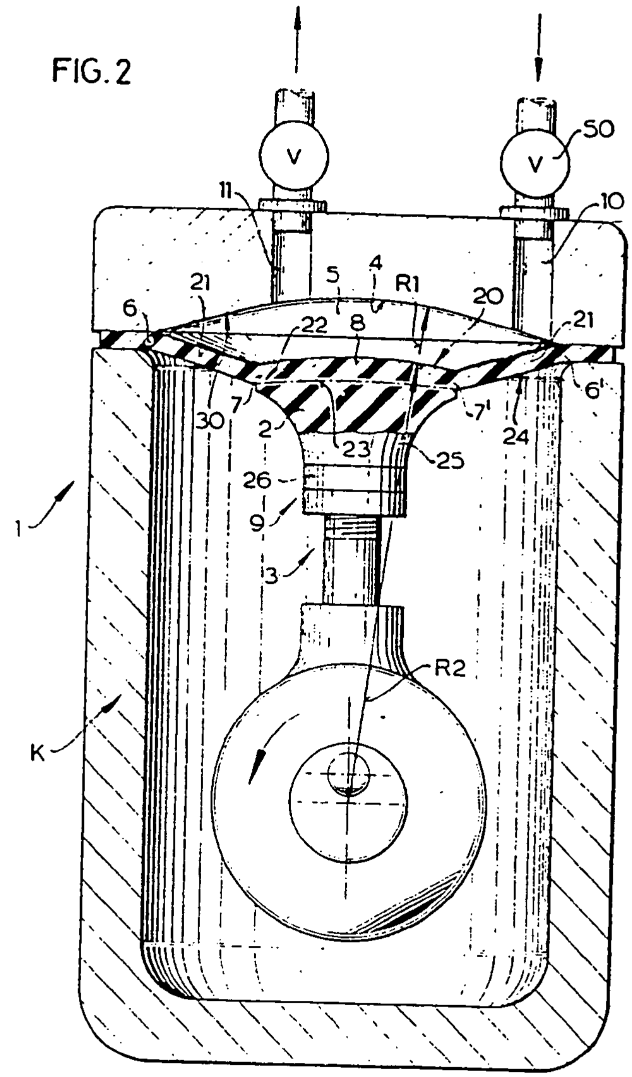


FIG. 2



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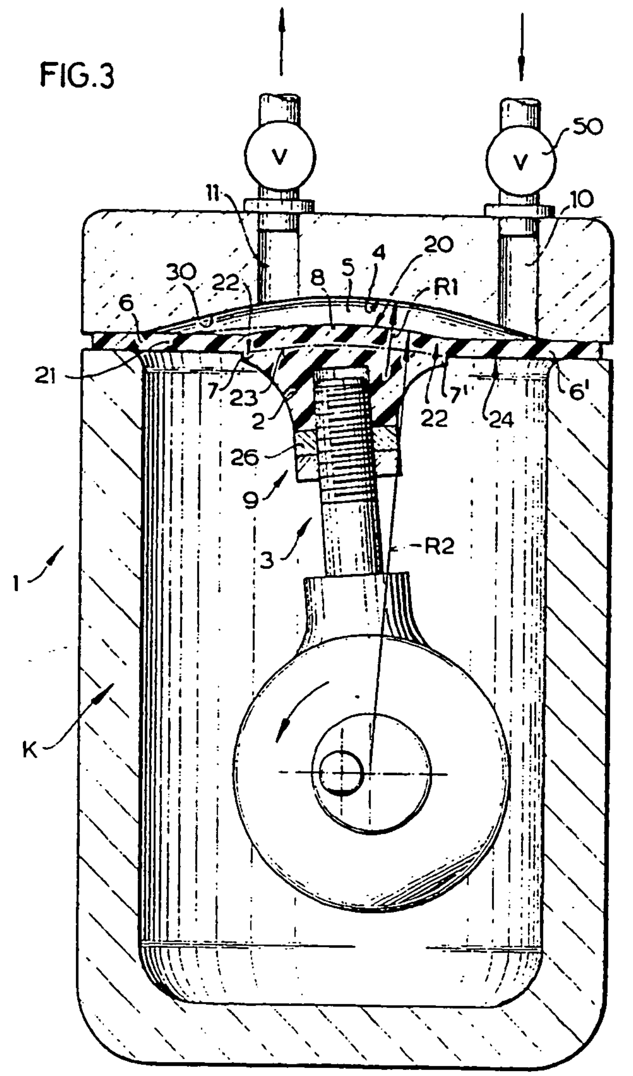
Sheet 3

FIG.3



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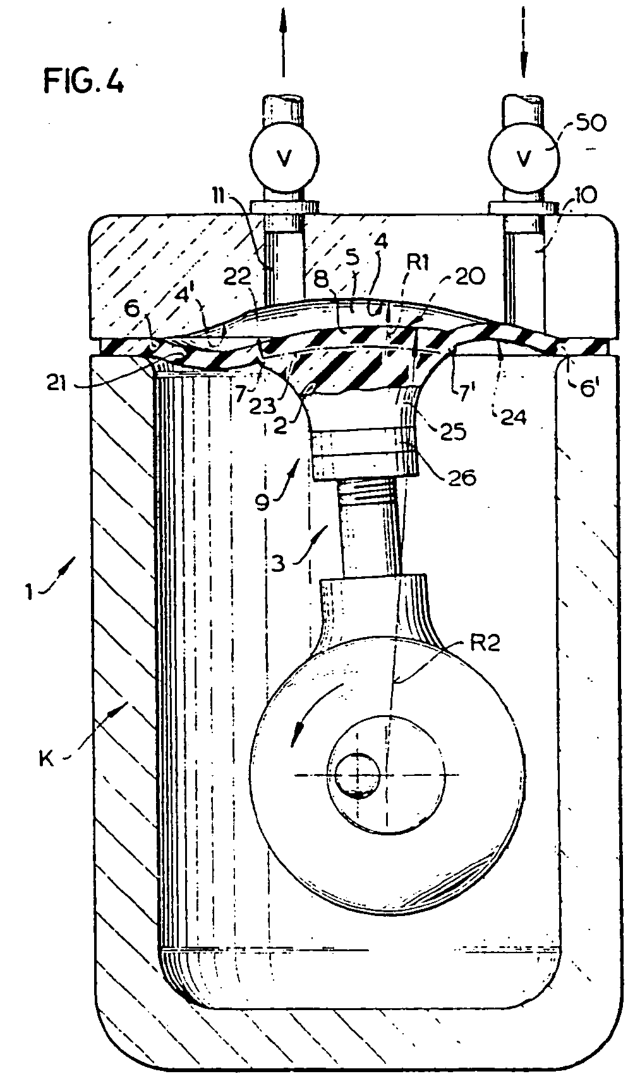
Sheet 4

FIG. 4



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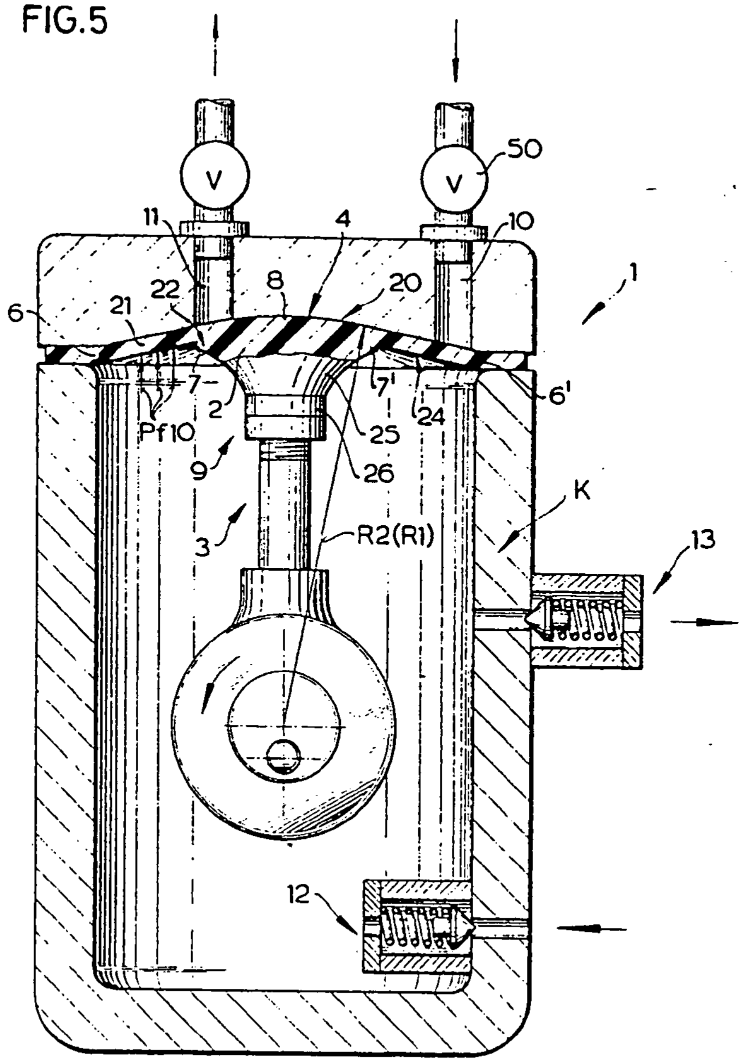
Sheet 5

FIG.5



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Sheet 6

FIG.6